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Defensive behaviour with stiff-legged posture in the Brazilian tree toads *Dendrophryniscus brevipollicatus* and *D. leucomystax* (Anura, Bufonidae)

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We observed death feigning with stiff-legged posture in several individuals of the Brazilian tree toads *Dendrophryniscus brevipollicatus* and *D. leucomystax*. This behaviour was formerly described for three other phylogenetically unrelated Brazilian leaf-litter frogs. Besides their cryptic colouration, tonic immobility during this posture strongly enhances the resemblance of these anurans to fallen leaves on the forest floor. This behaviour seems to have evolved independently in different lineages as a very effective defensive mechanism against visually oriented predators, especially vertebrates.

Introduction

Death feigning, or tonic immobility or thanatosis, as an anti-predator behaviour arose independently in several animal lineages. In neotropical frogs, death feigning was already reported in species belonging to the families Bufonidae (Haddad & Sazima, 1992, Abbadi-Bisogno et al., 2001; Russell, 2002, Toledo, 2004, Vaz-Silva & Frota, 2004), Cycloramphidae (Sazima, 1978), Dendrobatidae (Vaz-Silva & Frota, 2004), Hylidae (Sazima, 1974, Duellman & Trueb, 1994, Azevedo Ramos, 1995, Vrcibradic & Van Sluys, 2000, Gomes et al., 2002), Microhylidae (Sazima, 1978, Vaz-Silva & Frota, 2004) and Rhinodermatidae (Poulin et al., 2004). Death feigning with stiff legged posture, however, was described only for three cryptically coloured leaf litter frogs: the microhylid *Stereocyclops parkeri* (Wettstein, 1934), the cycloramphid *Proceratophrys appendiculata* (Gunther, 1873) (Sazima, 1978) and the leptodactylid *Scythrophrys sawayae* (Cochran, 1953) (Garcia, 1999).

Here we describe death feigning with stiff-legged posture in the Brazilian tree toads *Dendrophryniscus brevipollicatus* Jiménez de la Espada, 1871 and *D. leucomystax* Izecksohn, 1968 (Bufonidae) from three localities in the states of São Paulo and Santa Catarina, southeastern and southern Brazil.

MATERIAL AND METHODS

Dendrophryniscus brevipollicatus is a small toad (snout-vent length [SVL] ♂ 14.5 mm, ♀ 19.3 mm; HEYER et al., 1990) known from the coastal ranges of southeastern Brazil (HEYER et al., 1990; IZECKSOHN & CARVALHO-E-SILVA, 2001). This species is easily diagnosed by its small size, a pointed-mucronate dorsal snout shape, and reduced thumbs (HEYER et al., 1990). According to HEYER et al. (1990), it is apparently active on the forest floor during the day, resting on leaves above the ground at night. It is strongly associated to terrestrial bromeliads, where their eggs are laid and tadpoles develop (CARVALHO, 1949, LUTZ, 1954; PEIXOTO, 1995).

Dendrophryniscus leucomystax superficially differs from *D. brevipollicatus* by the presence of a white stripe extending from snout tip to base of arms, but several other differences distinguish these two similar toadlets (IZECKSOHN, 1968). The species is known from the lowland coastal forests of southeastern and southern Brazil (IZECKSOHN, 1968; WOLHL & WOLHL, 2006). It is a small toad (SVL ♂ 21.0 mm, ♀ 25.0 mm, IZECKSOHN, 1968) that is found in secondary and primary forests on leaves near the ground, including terrestrial bromeliads, and on the forest floor (IZECKSOHN, 1968, pers. obs.). Eggs are laid in temporary puddles on the forest floor, where tadpoles develop and attain metamorphosis (IZECKSOHN & CRUZ, 1972).

One individual of each species from localities in the state of São Paulo was collected, killed in a CO_2 artificial atmosphere, preserved in 10 % formalin and housed in the herpetological collection of the Laboratório de Zoologia de Vertebrados, Departamento de Ciências Biológicas, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, Brazil (field numbers IC 012 and CB 002). Voucher specimens (colour transparencies) from the state of Santa Catarina are housed in the herpetological collection of the Kansas University, Lawrence, USA (KU-CT 11954–11957).

STUDY SITES

Observations were made in three sites belonging to the Atlantic Rainforest Morphoclimatic Domain (AB'SABER, 1977), southern and southeastern Brazil, as follows.

(1) The Parque Estadual Carlos Botelho (PECB) is a 37793 ha reserve of well-preserved Atlantic rainforest located in the municipality of Sete Barras, state of São Paulo, southeastern Brazil (24°00'-24°15'S, 47°45'-48°10'W). Altitudes vary from 30 to 1003 m (DOMINGUES & SILVA, 1988). In the area where our observations were made, climate is Cfb of Koeppen, with the mean temperature of the warmest month not superior to 22°C (SETZER, 1946).

(2) The Parque Estadual da Ilha do Cardoso (PEIC) is a 22,500 ha island located in municipality of Cananeia, state of São Paulo, southeastern Brazil (25°03'-25°18'S, 47°53'-48°05'W). For the period 1990-1991, the minimum daily temperatures averaged 19°C and the maximum daily temperatures averaged 27°C, and the annual rainfall varied between 1800 and 2000 mm (MELO & MANTOVANI, 1994). Altitudes vary from sea level to 800 m. Our observations were made almost at sea level in a well-preserved dense Restinga.

(3) The third site is a well-preserved dense Restinga fragment located in Quatí, municipality of Guaramirim, state of Santa Catarina, southern Brazil (26°26'S, 48°57'W). Observations were made at 10m above sea level. Mean annual rainfall between 2002 and 2005 was 1900 mm. Climate is subtropical, with mean annual air temperature around 20°C (ANONYMOUS, 1997).

RESULTS

DENDROPHRYNISCUS BREVIPOLLICATUS

On October 8th, 2005, we observed death feigning in two individuals of *D. brevipollicatus* in PECB. At 12:11 h, one individual (SVL 17.5 mm) defended itself stiffing its legs in response to hand capture. The same behaviour was observed in another individual (13.7 mm) at 17:05 h (fig. 1a). We then gently rolled the toadlet around its longitudinal axis, simulating a bird beak with a finger, and observed that it remained immobile in its rigid posture (fig. 1b).

At the same site, on June 10th, 2006, four individuals displayed stiff-legged defensive behaviour. At 12:10 h one individual (SVL 15.4 mm) after disturbation maintained the rigid posture for almost five minutes. At 12:47 h one individual (16.8 mm) defended itself in response to searcher moving. At 14:42 h another individual (16.5 mm) feigned death several times following manipulation. At 21:10 h a female apparently bearing eggs (SVL 21.0 mm) adopted the stiff-legged posture.

DENDROPHRYNISCUS LEUCOMYSTAX

On July 9th, 2002, around 15:00 h, death-feigning was displayed by an adult *D. leucomystax* (SVL 16 mm) in Guaramirim Restinga fragment. When the animal was put upside down to be photographed, it remained in thanatosis posture (fig. 1c). On July 27th, 2002, between 14:00 and 17:00 h, at the same site, another individual (SVL 14 mm) was found on the leaf-litter and assumed the typical stiff legged defensive posture when touched by the searcher, remaining immobile for almost 1 minute (fig. 1d). Snout-vent length for the individuals (juveniles and adult males and females) sampled in this fragment varied from 14 to 22 mm (mean 17 ± 2 mm; $n = 29$).

On September 4th, 2005, death-feigning was displayed during the day (12:11 h) by an adult *D. leucomystax* in a Restinga area of the PEIC. After hand capture for identification, the toad was put upside down to take photographs of its ventral surface. It remained motionless

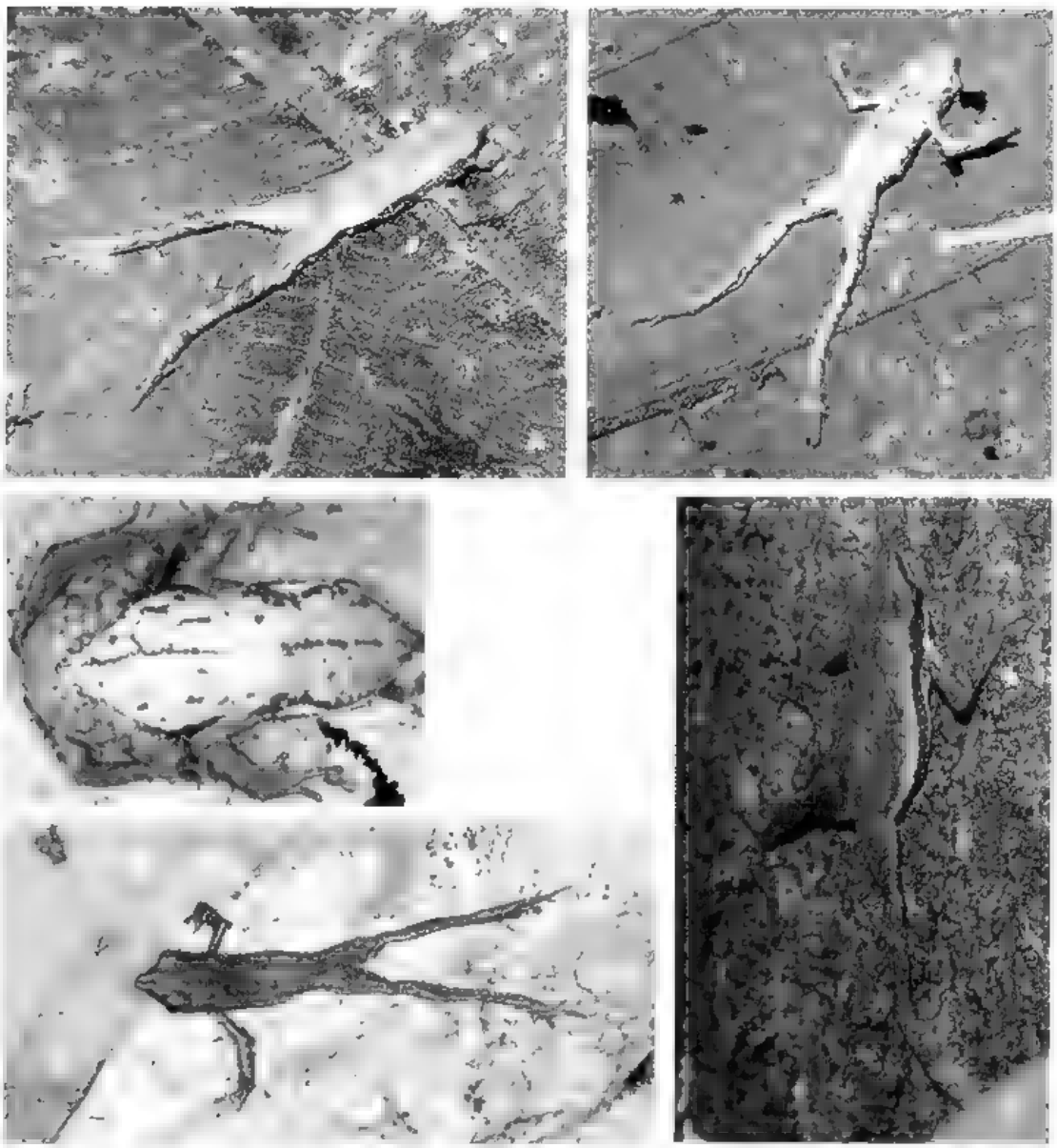

Fig. 1. Death feigning in the Brazilian tree toads *Dendrophryniscus brevipollicatus* (a-b) and *D. leucomystax* (c-e).

in a death feigning-like posture with eyes opened. We then caught the toad again and it leaped and landed on a leaf of a terrestrial bromeliad with the legs stretched backwards, remaining motionless and with eyes opened. The toad was photographed but not collected. On November 6th, 2005, at the same site, death-feigning by another adult *D. leucomystax* was observed during the day (17:39 h). After hand capture, the toad leaped and landed on a tree trunk, where it assumed the stiff-legged posture (fig. 1e). Two additional observations of this behaviour were made in 2006, on January 10th (09:42 h) and February 4th (15:33 h).

Discussion

Besides their cryptic colouration, the stiff-legged posture adopted by these toadlets greatly enhances their resemblance to fallen leaves both in colour and shape. As pointed out by Sazima (1978) for *Proceratophrys appendiculata* and *Stereocyclops parkeri*, tonic immobility in these cases may cause an animal to be confused with a casually dislodged leaf. This is suggested by the result of our simple experiment of rolling the animal around its axis. This defensive strategy may protect the individual against visually oriented predators like birds, snakes and mammals that actively search for their prey in the leaf-litter. The maintenance of the rigid posture for rather long periods – almost five minutes in *Dendrophryniscus brevipollicatus* and up to 10 minutes in *Scythrophrys sawayae* (Garcia, 1999) – suggests that this behaviour was selected against visually oriented predators. Similar predatory pressures on the forest floor possibly resulted in the convergent behavioural patterns observed in several unrelated frogs (Sazima, 1978). The instinctiveness of this behaviour is suggested by its being triggered and maintained in different species even in unexpected situations, like while submerged (Garcia, 1999) or vertically positioned on a tree trunk, or at night (this paper).

The related *Dendrophryniscus minutus* from the Amazonian region of South America also displays death feigning, but in a very different way. When captured, this toad flips over on its back and remains motionless in dorsal recumbency with the legs held upward. This posture makes evident the bright orange path on its venter and its orange palms and soles, thus consisting in a defensive behaviour associated to aposematism (Russell, 2002). Venter, palms and soles of *D. brevipollicatus* and *D. leucomystax* (fig. 1b-c) and of *Scythrophrys sawayae* (Garcia, 1999) do not have such warning colours, so these species did not evolve an aposematic behaviour similar to *D. minutus*. Thanatosis in dorsal recumbency, however, seems to be a common (probably primitive) defense strategy, since it was displayed by almost all individuals in different species and lineages that display stiff-legged posture.

Résumé

Une attitude de mort feinte, avec les pattes postérieures raides, a été observée chez plusieurs individus des Bufonidés brésiliens *Dendrophryniscus brevipollicatus* et *D. leucomystax* dans trois localités du sud et sud-est de Brésil. Ce comportement avait déjà été décrit pour trois autres anoures brésiliens non directement apparentés. Associée à leur coloration cryptique, cette immobilité tonique renforce la ressemblance de ces anoures avec des feuilles mortes tombées sur la litière forestière. Ce comportement semble avoir évolué d'une manière indépendante dans des lignées différentes comme un mécanisme défensif très efficace contre les prédateurs, notamment des Vertébrés qui effectuent une recherche visuelle des proies.

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